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NUMERICAL MODELING OF THE SEWER SYSTEM OF RIMINI (ITALY) AND STRATEGIES FOR THE CSOs REDUCTION ON THE ADRIATIC SEA

Extended abstract

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Background

Combined sewer systems are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same conduit. Combined sewer systems send wastewater to a wastewater treatment plant (WWTP), where it is treated and then discharged to a water body. During rainfall periods, however, the wastewater in a combined sewer system can exceed the capacity of the conduits and of the treatment plant. For this reason, combined sewer systems are designed to overflow occasionally and discharge excess wastewater to nearby channels, rivers, or other water bodies. These overflows, called combined sewer overflows (CSOs), although diluted contain stormwater and also untreated human and industrial waste, toxic materials and debris. In the last years new sewer systems are designed separated and with the introduction of LID (Low Impact Development) strategies (Gambi et al., 2011), but we have also to cope with old combined sewer systems and it is important define strategies for their best management.

The environmental impact of CSOs are considered, although indirectly, in several EU Directives and the wastewater Utilities must face the challenge to contribute to the Good Ecological Status of the water bodies that are influenced by their infrastructure. Historic data sets of registered pollutants discharged by CSOs proved the relevance of CSOs spills (Marinelli et al., 1997). Although conclusions depend on the pollutant under consideration, in general CSOs impact cannot be ignored (Dirckx et al., 2011). The first evidence of CSOs impacts on the receiving water bodies came to light in the 1960s but it was not until the 1990s that reducing the CSOs became a concern, because the most visible dry-weather pollution had been reduced by a systematic construction of WWTPs. Among the major effects caused by the CSOs is the acute short-term impact due to dissolved contaminants, bacteria and viruses, causing fish death, health risks and making water body unsuitable for the intended use (drinking water, bathing, etc.).

Objectives

The main objective of this work was to analyze the behavior of the sewer system of the city of Rimini, located in the Northern part of Italy. It is characterized by a sewer system with a total length of about 736 km (56% is combined). Sewage flows into two WWTPs, which are designed for dry weather period and can't cope with discharges exceeding two- three times the dry weather flow. Thus, during rainfall events, in order to protect the city and the WWTPs, CSOs are activated and great part of the flows is diverted out of the sewerage. In particular 11 CSOs spill to the Adriatic Sea and this is great problem for the city, in fact Rimini has an economy based on tourism, the activations of the CSOs along the coast, especially during the summer, determines great problems both environmentally and economically.

Rimini sewer system is very complex. It consists in 52 pumping stations, 6 detention ponds with a total volume of about 114'000 m³, and 4 first foul flush tanks with a total volume of about 17'000 m³. In order to manage the discharge, during rainfall events, and to control the resulting CSOs spills, 28 movable gates are controlled in real time through water level gauges.

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Outline of the work

This work is divided in two main parts: development of the mathematical model of the sewer system and its calibration; analysis of different strategies for the mitigation of the CSOs impact on the Adriatic Sea.

The mathematical hydraulic model was developed using InfoWorks CS developed by Innovyze Ltd, integrated urban sewage drainage software with the functions of rainfall-runoff, water quality, and sediment transportation simulations. In this kind of sewer, very complex, the support of a mathematical model is fundamental in order to know, in the best way: water levels, discharges, pollutants, etc. (Calabrò and Maglionico, 2002; Freni et al., 2008).

Methods

The number of total nodes of the numerical model of the sewer system of Rimini is about 11'000. The model was calibrated using measured water level every 15 minutes in several pipes, tanks, pumps and movable gates functionality. The water level derives from a sophisticated system of real time control (RTC) and it is essential for monitoring the state of sewer storage or to convert levels to flow rate where backwater effects are not dominant.

The calibration process followed two steps. Firstly the system was analyzed in dry weather conditions. Collected measures of water level for the period 21- 25 May 2009, were compared to water levels, simulated by the model. The daily trend of the water level in dry conditions depends on the on/off of the pumping stations and on the user behaviour. In particular the sewage flows were obtained from the insertion of the annual water consumption. Two types of coefficients were used in the mathematical model for simulating the variability of wastewater flow. The first one is the hourly coefficient that allows the average flow to adapt to the real consumption. The average flow is multiplied by a coefficient less than 1 during the night to simulate the minimum consumption, while peaks are during the day. The second is the monthly coefficient used to simulate variation in water consumptions due to touristic fluxes. Rimini is indeed characterized by a high number of tourists during the summer. This coefficient based on data provided by the Statistical Office from the Province of Rimini, which contain, for every day of the year, tourist arrivals and overnight stays for the entire Province.

In the second calibration step measured and simulated water levels in wet weather conditions were compared. Different rainfall events, recorded with time step of 5 minutes, during 2008 and 2009 were used to calibrate the model. Rain data were collected by three tipping bucket rain gauges. The process was done manually, while a trial and error parameter adjustment was made. In this case, the goodness-of-fit of the calibrated model is basically based on a visual judgment by comparing the simulated and the observed hydrographs. The mathematical modeling of the network allowed the evaluation the volumes of water spilled from each CSO, as well as TSS masses, BOD₅ or COD, thus allowing estimating the environmental impact.

During rainfall events the greater part of stormwater spilled by the whole CSOs system, is sent to the Adriatic Sea by 11 CSOs. The rain series used for the simulations was one year long, from 01/01/2009 to 31/12/2009. The adoption of real rainfall time series allows also to take into account the dry weather periods among rain events which are of fundamental importance to estimate the buildup of pollutants and therefore the quality of the waters that flow into the sewer system during rain events.

Results and discussion

The mathematical modelling of the network has been used to evaluate: the volumes of water spilled from each CSOs, the mass of TSS, BOD₅ or COD. It allowed estimating the environmental impact of the CSOs, the frequency of discharge, and the degree of dilution including those with more complex geometry.

Real-time control (RTC) is a custom-designed computer-assisted management system for a specific urban sewerage network that is activated during a wet-weather event. Uses and benefits of RTC are multiple (Newman et al., 2004), particularly the advanced types, can perform a variety of management functions in a given sewerage system:

- control flooding, overflows or surcharges;
- maximize storage volume;
- optimize treatment plant capacity;
- prevent operational problems and protect receiving waters.

This paper focuses on storage optimization to protect receiving waters, in fact RTC uses in-network storage (that is much less expensive than constructing conventional storage facilities) and enables more effective use of conventional storage facilities. Increasing the capacity for temporary storage of the network is essential to reduce overflow discharges into the Adriatic Sea.

The first part of this study analyzes the benefits resulting by the use of RTC techniques applied to two sewer basins of the whole sewer system: Colonnella 1 and Colonnella 2 (Fig. 1). For the simulations were considered 107

rainfall events obtained combining the events with an inter event time of at least 12 hours and a minimum depth of 0,2 mm, collected on yearly base (2009).

At the basin closing section of Colonnella 2, the flow is diverted by a pumping station to the Colonnella 1 basin. During rainfall events, if the flow exceeds the Colonnella 2 pumps maximum capacity (340 l/s), a spill occurs. Colonnella 1 pumping stations has a similar behaviour: if the flow exceeds pumping station maximum capacity (690 l/s), a spill occurs to the Adriatic Sea.

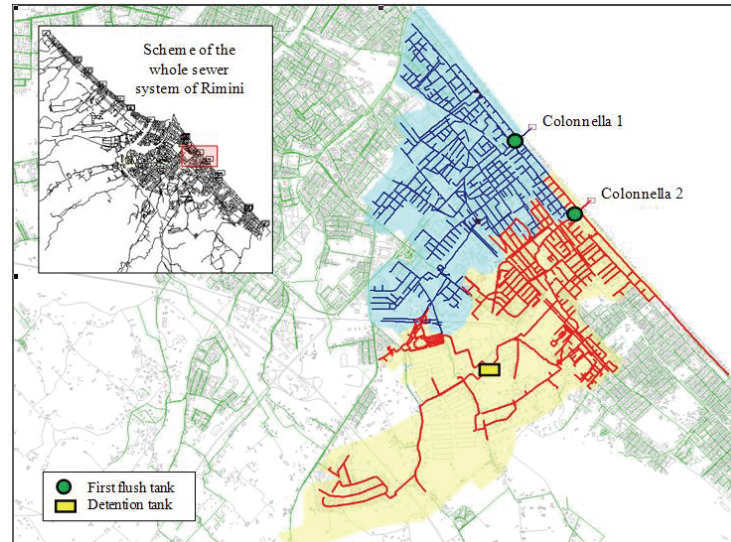


Fig. 1. Subcatchments drained by Colonnella 1 and Colonnella 2

Table 1. Differences between measured and predicted L_{A10} at different floor levels

	<i>Colonnella 1</i>	<i>Colonnella 2</i>
Shape	Rectangular	Rectangular
Width, mm	3.900	3.100
Height, mm	1.800	1.500
Slope, %	0.117	0.017
Area, ha	225	415
Impervious area, %	76	64

The primary focus in terms of control of the system is reducing CSOs volume spilled from Colonnella 1 and Colonnella 2, for this purpose three scenarios were studied:

- I. CSOs with fixed weir;
- II. CSOs with sluice gate and RTC based on water level;
- III. CSOs with sluice gate and RTC based on water level and tanks.

The first scenario involves the insertion of two fixed weir for the regulation of overflow. The considered weirs have a fixed height equal to 25 cm for the Colonnella 1 and 48 cm for the Colonnella 2. They have been dimensioned in such a way in order to ensure the overflow only when the flow is equal to 5 times the average sewage flow in dry weather conditions.

The second scenario involves the insertion into the sewer system of sluices gate with RTC that was designed to optimize the sewer storage, by controlling the combined sewer overflows. The RTC sets the opening or closing of sluice gates by measuring the water levels upstream.

In the third scenario three reservoirs were included, actually present in the sewer system of Rimini. The first tank, located upstream of the Colonnella 2, has been inserted to solve the hydraulic criticalities of this zone, it has a volume of 30'000 m³ corresponding of about 300 m³/ha_{imp}. The emptying of the tank is obtained with a pumping system that diverts the water to the artificial channel Deviatore Ausa, (that flows to the Marecchia River and thus out of the sewer network), in order to reduce the flow downstream. The second tank is a first flush tank that capture the first part of rainfall in order to ensure water quality It's near the pumping station Colonnella 2 and it has a volume of 4'600 m³ (corresponding to 17.4 m³/ha_{imp}). Downstream of the two previous tanks described, near the Colonnella 1, there is the third tank. It is a first flush tank with a volume of 3'000 m³ (corresponding to 17.2 m³/ha_{imp}). Both first flush tanks are emptied 24 hours after the rainfall event by a pumping station that sends the flow to the WWTP.

The three considered scenarios provide increasing benefits in terms of reductions of the number of overflows. In particular the introduction of fixed weir (Scenario I), for the CSO Colonnella 1, brings a reduction in the number of overflows of 39% (respect total rainfall events), this value rises up to 68% with the introduction of the sluice gate and of the RTC system on the water levels (Scenario II). In the third scenario the overflows are 27 that correspond to

a reduction of 75% in the number of overflows respect to the total number of rainfall events. For the CSO Colonnella 2 the percentages of spill reduction for the three scenarios are respectively the 43% (fixed weir), 49% (sluice gate and RTC) and 73% (sluice gate and RTC and tanks)

In the Fig. 2 is possible to observe the characteristics of rainfall events, in terms of total depth and intensity, which can activate the two CSOs for the last two scenarios analyzed. For instance the activation of CSO Colonnella 1 in Scenario II requires rainfall with intensity and depth that are greater respect the rainfall that can activate the CSO Colonnella 2. This kind of analysis allows to characterize each CSO in terms of sensitivity to the rainfall characteristics and its environmental impact on the receiving water in terms of number of spills.

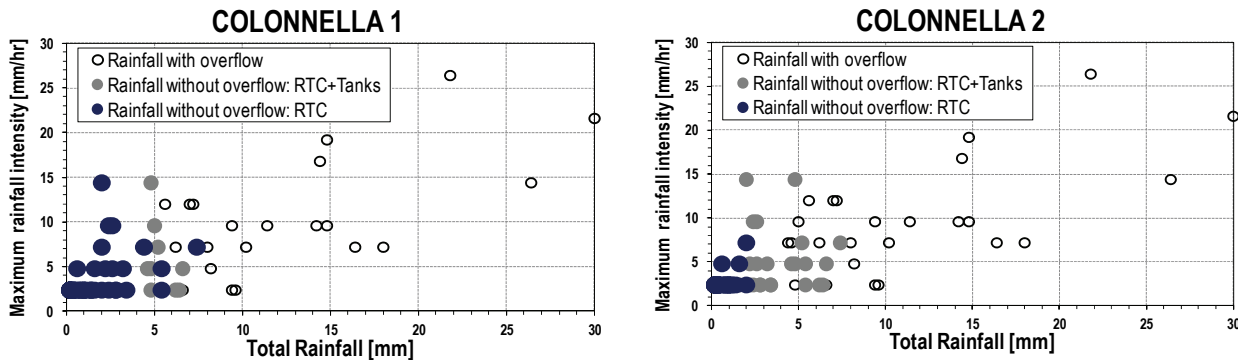


Fig. 2. Effect due to RTC and Tanks on CSOs for the 107 rainfall events simulated

Concluding remarks

This work analyzes two important CSOs present on the sewer system of Rimini: Colonnella 1 and Colonnella 2. In particular it was evaluated the efficiency, in terms of number of spills during rainfall periods, with different configurations. The simulation of the three different scenarios shows the benefit due to RTC and to the tanks located in the sewer system in terms of spill reduction on the Adriatic Sea. The RTC, respects the fixed weir, increase the efficiency of about the 17%, and the adoption of small tanks allow to increase the efficiency of about the 15% respect the only RTC.

Keywords: Combined Sewer Overflow, Numerical modelling, Rimini, RTC, Sewer System

References

- Calabrò P.S., Maglionico M., (2002), *Comparison between a detailed model and two simplified models in urban stormwater quality simulation*, Proceedings of the Global Solutions for Urban Drainage - IX ICUD Conference, Portland (OR).
- Dirckx G., Thoeye Ch., De Gueldre G., Van De Steene, B., (2011), CSO management from an operator's perspective: a step-wise action plan, *Water Science and Technology*, **63**, 1045-1053.
- Freni G., Maglionico M., Mannina G., Viviani G., (2008), Comparison between a detailed and a simplified integrated model for the assessment of urban drainage environmental impact on an ephemeral river, *Urban Water Journal*, **5**, 87-96.
- Gambi G., Maglionico M., Tondelli S., (2011), Water management in local development plans: the case of the old Fruit and Vegetable Market in Bologna, *Procedia Engineering*, **21**, 1110-1117.
- Marinelli A., Maglionico M., Artina S., (1997), *Water Quality Simulation in an Urban Drainage Catchment*, Proceedings of the European Water Resources Association Conference, Copenhagen, Denmark, 383-390.
- Newman T., Rozelman S., Gibbons S., Vitasovic C., Kerr J., (2004), *Analysis of Operational Strategies and Real Time Control in an Urban Sewer Network*, In: *Global Solutions for Urban Drainage*, ASCEE, Online at: [http://dx.doi.org/10.1061/40644\(2002\)318](http://dx.doi.org/10.1061/40644(2002)318).